Summary of the CREZ Reactive Study

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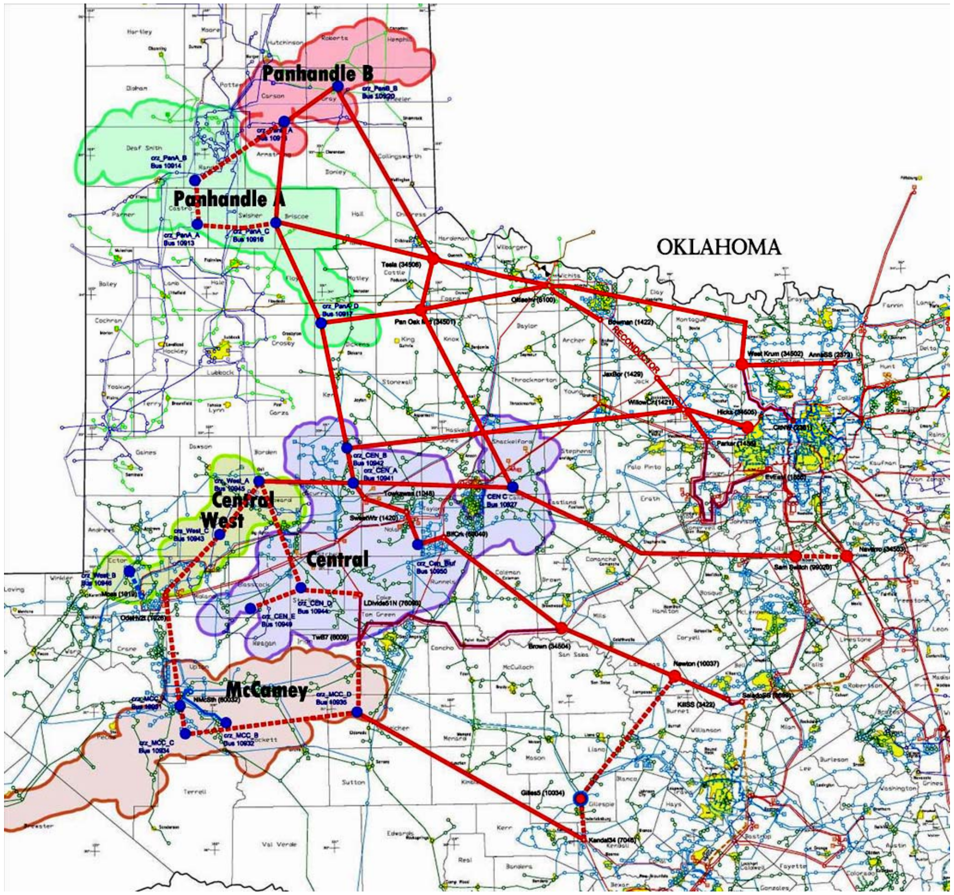
Project Overview



The CREZ Reactive Study had three major work areas:

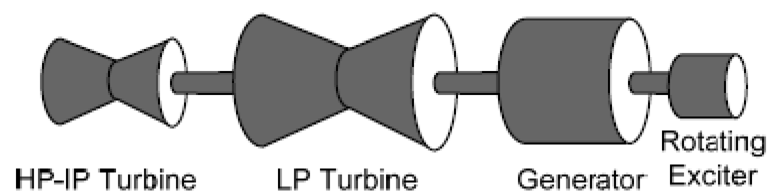
- Review and optimize design specifications of CREZ series compensation
- Review and optimize the location, size and response requirements of shunt compensation
- Evaluate potential impacts of sub-synchronous interactions

CREZ Reactive Study was managed in a joint effort by ERCOT and the CREZ TSPs

The study was conducted by a team of consultants from ABB, Inc.

A Few Definitions

- **Shunt Reactive Device: a device that is connected alongside (parallel to) the current flow in a transmission system that either provides (capacitor) or consumes (reactor) reactive power**
- **Series Reactive Device: a device that is connected in line with (in series with) the current flow on the transmission system.**
- **Sub-synchronous frequencies: frequencies on the power grid that are lower than the fundamental frequency (60 Hz or cycles per second)**
- **Sub-synchronous resonance (SSR): when sub-synchronous frequencies interact with mechanical characteristics of generating plants to create potentially damaging stress along the turbine shafts**



- **Sub-synchronous Interactions (SSI): Potentially damaging interaction between power electronics devices (such as wind turbines) and sub-synchronous frequencies.**

Study Cases

- **The following system conditions were analyzed as part of this study:**
  - Minimum Exports (Low wind, low load)
    - Used to indicate the need for equipment to control circuit voltages under low-wind conditions and initial circuit energization
  - Peak Load
    - Used to indicate system reactive needs under high load conditions
  - Initial Build Case
    - Developed to reflect the reactive needs of the CREZ system while maintaining flexibility to adjust the reactive plan to meet evolving system needs
  - Maximum Exports (High wind, low load)
    - Used to indicate reactive needs under maximum loading of CREZ circuits
    - Results indicate a need for reactive devices to supplement localized system current strength (such as synchronous condensers)

	2008 CREZ Study (CTOS)	Minimum Exports	Initial Build	Maximum Exports
Wind Installed Capacity MW	18,455	21,958	17,517	21,958
Wind Dispatched Level MW	12,975	2,562	12,802	15,430

Sub-Synchronous Interaction Analysis

Several different potential issues associated with use of power electronics on transmission systems:

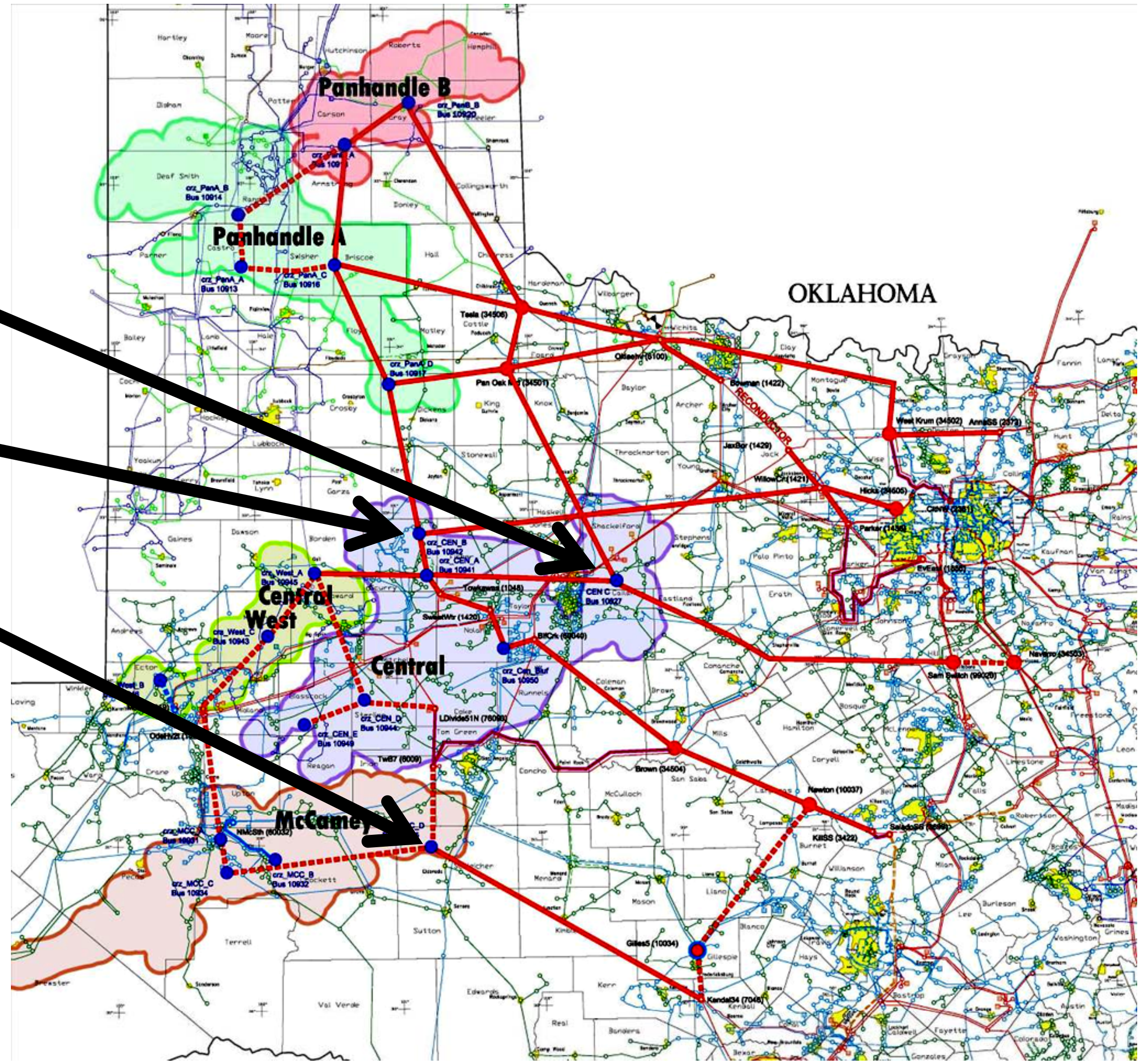
- Sub-synchronous Resonance (SSR) – primarily a concern for large synchronous generation units
  - Potential impacts to 6 existing generations units were evaluated (Comanche Peak, Tradinghouse, Willow Creek, Oklaunion, Hays, Odessa)
- Sub-synchronous Torsional Interactions (SSTI) – results from operation of power electronics devices near large synchronous generation units
  - Study results indicate this should not be a significant issue
- Sub-synchronous Interactions (SSI) – impacts to wind turbines were evaluated for a small set of turbines (very few PSCAD turbine models were provided by vendors). Potential impacts noted at several locations on CREZ system.
  - There are transmission system and turbine-specific mitigation options

Geography of SSI

Locations most prone to have Sub-Synchronous Interaction (for Type 3 turbines):

1) West Shackelford – SSI with no contingencies
2) Dermott – SSI after 1 contingency
3) Big Hill – SSI after 1 contingency

Locations directly connected to a compensated line or potentially in a radial or semi-radial configuration following the outage of one or a few nearby circuits will be SSI prone.



Conclusions

- ERCOT recommends installation of the reactive devices specified through analysis of the Minimum Exports, Peak Load, and Initial Build cases
  - Will provide necessary reactive capability for initial energization of the CREZ transmission system and for significant subsequent build-out of wind generation
  - Will provide flexibility to adjust the location and size of additional dynamic reactive devices to reflect actual development of wind generation and other changes to the transmission grid
  - Analysis of maximum CREZ export conditions provides a potential build-out for the full CREZ system. Delaying full implementation will provide time to evaluate alternative reactive solutions to mitigate low system strength conditions.
  - Any additional reactive capability needed to support the CREZ system (beyond current recommendations) can be planned and implemented in a timely manner
- Further study needed:
  - Identify new tool and conduct studies of potential solutions to low system strength conditions
  - Evaluate options for SSR/SSI mitigation
    - Procure modeling capability to analyze implications of SSI in future studies
    - Modifications to Generation Interconnection requirements/process

Reactive Device Recommendations

The following shunt capacitive devices are being recommended:

Station	Static Capacitors (MVAr)	Dynamic Reactive Devices (Static Var Compensator [SVC] - MVAr)
RILEY	316	
KRUM	50	
TESLA		+300 (-100)
EDITH CLARKE		
SILVERTON		
COTTON		
SCURRY	100	
WEST SHACKLEFORD		
GRELTON	50	
BROWN	200	2 x [+300 (-100)]
KILLEEN	100	
BIG HILL	144	
PARKER		+300 (-100)
HAMILTON		+200 (-50)

In addition, ~-4,000 MVArs of shunt static reactors will be required, at 30 substations, for voltage control under low wind conditions and for line maintenance and operations.

Estimated costs:

Shunt Capacitors: ~$25 M

Static Var Compensators: ~$150 M

Shunt Reactors: ~$220 M

Questions?